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[Please stand by for realtime captions]

Welcome to the NOAA Central Library! We are happy to host Carey Kuhn today, an ecologist from the Marine Mammal Laboratory a division of the Alaska Fisheries Science Center. She joined the Mammal Marine Laboratory in 2007 after completing her PhD in Ecology and Evolution at the University of California Santa Cruz . Her research uses bio-logging technology to examine the at-sea behavior of northern fur seals with the goal of understanding relationships between fur seals and their prey.

Thank you for coming today. I will talk to you about the research we are doing and today we will focus on northern fur seals and using saildrones.

To start by recognizing all the team members that were involved in the research. It was a group of scientists and engineers that work together. This work was a collaboration between two NOAA line offices, NOAA Research and NOAA Fisheries, and our team members were made up of federal employees and employees from a collaborative institute. We worked in six research teams, and we worked with three private companies.

There will be contact information at the bottom of the slides, for the the people who led the specific project I'm talking about. If you have more detailed questions I can refer you to those individuals.

The saildrone mission was conceptualized and led by the ITAE program from the Pacific Marine Environmental Lab. And ITAE is the Innovative Technology for Arctic Exploration, this group uses innovative technology to do high resolution monitoring of the Arctic, and through a cooperative research and development agreement, with Saildrone Inc., they started instrumenting these saildrones with sensors to measure atmospheric and oceanographic conditions and also test whether the saildrones are a good platform to survey the Arctic environment.

This is the Saildrone, it is an unmanned surface sailing vehicle, these were created for

long-distance and long-duration ocean data collection missions, they are deployed and recovered from the dock and can navigate to the research area of interest. They use wind power for propulsion, solar power for electronics, and the data is collected and transmitted via satellite so you can get it in real time.

The Saildrone carries a suite of scientific instruments, this shows you what it can measure, these are atmospheric, surface, and subsurface sensors, we do not use all of the sensors, the ones shaded in gray were not used during our missions.

In 2016 when NOAA Fisheries joined the saildrone mission and that was with a passive acoustic recorder for mammals and an echo sounder to measure fish biomass.

We will skip over here, we had a problem with our video.

This is a short video of a Saildrone in action, this was recorded in the 2015 inaugural science mission, this is when the two saildrones launched from Dutch Harbor to measure the Bering Sea over a couple of month mission.

This was a plot of some of the mission variables that were recorded over the 2015 mission, unfortunately we had problems with our videos in this presentation.

I will mention the 2015 mission was for just environmental sensors, this was the first test of saildrone in the Bering Sea. In 2016 we started doing ecological measurements as well.

Now, we will focus on the 2016 and the 17 missions. The overarching goal was to monitor oceanography, whales, fish and fur seals in the Bering Sea. There were six research groups that worked together in order to identify goals of our own and integrate these into a single mission, there were conflicting priorities but we worked together to find a way to make the research work. One of those research goals was to continue the engineering and development of our sensors, and continue to collect real-time data. As you can imagine in the first deployment problems were identified and lessons were learned and development continued.

The second goal was to test the effectiveness of a low-power echo sounder that was adapted for Saildrone measurements. This was done with doing follow the leader type surveys, the Saildrone would go through a path and research vessel would follow behind and measure data.

In 2017 we added an additional goal and that was to use the Saildrone to see if regular acoustics surveys needed to be expanded into other areas, so the saildrone went outside standards survey areas to see if walleye pollock were in those areas.

I told you about the passive acoustic recorder, the goal was to listen for marine mammals in the Bering Sea and document their presence and location with a target of the critically endangered north pacific right whale. There are 30 left. Surveys are rare for this so the hope was the Saildrone could expand the survey area and augment the mooring detection systems at the Bering Sea. In the final goal, where I joined the project, was to use the Saildrone to understand the relationships between fur seals and their prey. So we used the Saildrone to map the vertical and horizontal distribution of walleye pollock and track fur seal behavior in order to link those together to see how fur seals change their behavior.

Before we move on, I wanted to show you some statistics, we had two saildrones in 2016 that covered 12,000 km, it ran from May through September, in 2017 there was a single Saildrone in the Bering Sea, but two additional they moved into the Arctic, that mission covered 14,000 km in the Bering Sea. If you want more details about the 2016 mission, and the results, I refer you to the Mordy, C.W., et al publication in *Oceanography* from 2017 and it describes the goals and some of the research results.

Moving on to the first part of the mission, to get started I will give you some background about the species, the status and how the saildrones help us understand important information that is missing. The Eastern Stock of fur seals is found during the summer months in the Bering Sea, this is where it breeds, this stock is considered threatened, one step above endangered. So they breed on Pribilof and Bogoslof Islands.

In recent years in the past, this population used to be three quarters of the world's population of Fur seals but has declined rapidly.

This is a plot of our population trend for the fur seals, it is plotted as the number of pups. It starts in the early 1900s goes through 2016. In the early 1900s, with the end of the pelagic harvest you can see rapid growth of the population and a short period of stability. In the late 1950’s there was an adult female harvest which was followed by a rapid population decline, In the gray section, about 70% of the decline can be explained by modeling the removal of those females and their dependent pots. About 30% of that decline cannot be explained. The harvest, the female harvest, ended here in the late 1960s. Later you can see the recent years continuing to decline which is of concern for us.

In 2016, it was at the lowest pup production in over 100 years.

The red dots here, they counts from the Bogoslof Island population but note the scales are not the same. This population was established in the 1980s, two pups were found in 1980 and the

population grew rapidly which is great news however Bogoslof is an active volcano. In 2017 a number of large eruptions occurred, some during the breeding Period and the island was completely reshaped. We have no idea what happened to the fur seals in the population. This is a big concern, we cannot get back until the volcanic activity stops.

You can see the differences in our population when you look at all photographs, this is from 1948. All those black dots are Fur seals it is almost a continuous carpet. This is from 2005, the same location, it is challenging to gather up the Fur seals they are along the shoreline in this rocky area. 2016 was the lowest in 100 years, Fur seals than what we see here now.

We know the demographics, the population trends are linked to their annual life cycle which is split into two phases. The first phase is the winter migration that brings fur seals out of the Bering Sea into the Pacific and California current. They spent eight months at sea from November until June, in June breeding animals return and spend the rest of the summer months in the Bering Sea. They spend their summer in the bearing for breeding.

While they are there, the females have to alternate time on land nursing a pup and time at sea to obtain resources to support themselves through the summer. A pup is 100% dependent on the mother and while the females are away forging the pup is fasting. This means the females are highly dependent on local resources around the colonies, if they can't find local prey they have to travel further and stay away for a longer period of time.

We know that the pup growth is related to females foraging trip durations. This is a plot of pup growth in grams per day, plotted over the ratio of the trip duration divided by the shore duration. As females spend a greater proportion of their time away, the pup growth rates decline. These pups are completely independent at weaning during their first winter migration. We know that, for male pups at least, size at weaning is related to survival.

There is a northern fur seal conservation plan in place with the goal of conserving and recovering the population to its optimal population size.This plan list a number of critical information gaps which are areas where more information is needed to effectively conserve and manage the population. One of these gaps is a need to better understand functional relationships between Fur seals and their prey. This is where the Saildrones are the most valuable to us. During the summer months, fur seals that forage on the Bering shelf primarily consume walleye Pollock. The frequency of occurrence in the diet is 60 to 80%, it is an important species, for the Fur seals. Pollock is also the target of the largest US commercial fisheries by volume and second largest in the world. So there may be a conflict between the fur seals that need this food to survive and the fisheries, however we need to understand the relationships to see if this conflict exists.

Because of the commercial importance this stock is monitored annually, surveys occur in the summer months. This map shows the survey path and it is colored by day, the survey start in June, and they run through August. This is the fur seal foraging area, you can see the survey comes through this area in the first week of July. The Fur seals arrive in June and stay there through November, and we don't have information about their prey throughout the summer.

This temporal mismatch makes it challenging to understand the relationships between the Fur seals and walleye Pollock. Potentiall we can use Saildrones to extend the surveys into the time frame that is important to the Fur seals.

As I mentioned, as part of our mission, the saildrones were equipped with new echosounders and we needed to study whether or not this was a valid platform to do these studies. We did this by doing follow the leader studies. On this map here, the gray lines are the tracks from the Oscar Dyson, the red lines and blue lines are the paths of the two different Saildrones. The follow studies occurred here, and over here, where they met up to do the surveys. We collected the data at the end of the mission and compared the results to see if this is a good survey. The results, very simplified were the Saildrone can collect high quality data and it appears to be a suitable platform. There are caveats, a large amount of data was collected which requires extensive processing once it came back, months of processing. If you'll use this tool to save time and effort, you have to compare that to the efforts afterwards. There were weather affects. In high wind conditions the data was compromised, that is one thing to be aware of, there may be issues with the data. With all echosounder studies, there is no information about species or size of fish, you are recording. So, in most cases trawl surveys are done with echosounder surveys.

Trawls are done at the same time by the Oscar Dyson, each of these dots is a trawl and you can see it covers the Saildrone survey area pretty well. The results of the trawls was the primary fish is the walleye Pollock. We know this from our history of surveys, that pollock the dominant fish on the shelf in the Bering Sea. This makes it an ideal environment to do these studies, we already know what the fish is, and so one of the caveats is in a different environment, where there is greater prey diversity you may not be able to interpret the data without the surveys.

So we mapped out our prey, and once we got the data back, we classified the fish into two different categories, based on the trawl data and what we know about pollock behavior. This is a plot of what the data looks like, there are two different categories, there is shallow, age-0 pollock and you can see this in the band, and the second category was the adult pollock found deeper in the water column, these are some examples here. Now we have an idea of the distribution of the prey classified into the age classes and we can see how these different variables impact the behavior.

For the fur seal data, there is a long history of tracking behavior at the Pribilof Islands and we use this information to help design the study for our tracking in 2016. First we targeted animals that breed on the northeast side of the island, because we want to make sure they are staying on the Bering shelf. There are diet differences depending on where a seal breeds on the island so we want to keep just shelf feeders in the study. We summarized hourly locations over seven years of research, from July and August in particular, calculating the core usage area for this breeding location, this helps us select an area that we predict the fur seals would use in 2016. This plot is 10 km grids colored by the use. This area in the red box is what we predict the core usage will be and we set the Saildrones to survey this area. But, at any point during the survey we can say, we need to go somewhere else, this area looks interesting let's go here. We can make adaptive changes to the survey plan..

The fur seals were tracked and we measured dive behavior. We track 46 adult females total in both years from July to October. The instruments are glued onto the fur and when we recapture the seals we cut the hair to remove the instrument. In 2017, a subset of seals were also equipped with video cameras and accelerometers to record prey captures.

Using the cameras we can see the species and the class-size consumed which is important information to help with the diet models. This is the track for the Saildrones in 2016. I told you we have a core area we targeted, but the echosounders ran continuously so we were able to use all the data for analysis. In 2016, the Saildrone spent 103 days at sea, covered 12,000 km, and 65 sampling days occurred in our core fur seal area. Each of the saildrones covered this area one time, one started in the north, and the other in the South, and they moved through the area of interest.

This is the track from 2017, there was only a single Saildrone in the Bering Sea, it was a 76 day mission, covering 14,000 km, and we had 36 days in our area, which was expanded. I also want to point out, this segment of track to the north was where the Saildrone explored the area outside of the standard acoustic trawl survey to see if it is necessary to extend the survey.

From here on out, I will show you some of the results, all of the data is from 2016. 2017 data is still being analyzed. So, all the data are preliminary. This is data from 2016, this is the backscatter data, interpolated on 10 km grid cells. Age-0 pollock on the left, and the adult pollock on the right. They are colored by backscatter density, the high density is in red, low density is in blue, you can see a large amount of age-0 backscatter here in the middle shelf region, and the adult Pollock is more distributed to the north and the outer shelf areas and some here in the middle shelf area.

The fur seal behavior was interpolated on the same 10 km grid pattern, we had 34,000 hours at sea, and over 284,000 dives. This map here is density of hourly locations with high usage area in red and blue around the outside. Fur seals expand their trip distances as the season progresses so these trips out here tend to be later in the season.

Although this is preliminary analysis, there were some obvious patterns.

The time in a grid cell was positively related to backscatter and this relationship improved when you look at backscatter during the nighttime. As the backscatter increased, fur seals spent more time in a grid and you can see this relationship spatial when you look at the use map with the backscatter. These maps are slightly offset, so I circled the overlapping areas in black. You have the high use areas here for the fur seals and that is in line with a large area of pollock backscatter..

This is for all the fur seals combined, but not all the fur seals do the same thing.

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12 fur seals showed the same pattern, with increase in time related to higher age-0 backscatter. 4 showed a positive relationship with backscatter from the adult Pollock and these animals foraged to the north of St. Paul in this area of the higher backscatter. For the rest of the animals in 2016, there was no relationship and this can occur for a number of reasons. The first, is a more variable forging pattern, generally the fur seals will forge and go back to that same spot over the summer, some individuals choose not to do that, they will go to the north on one trip and the east on another. Now we have this variability. We don't know if it is related and what is the cost but it could make these relationships less clear. We could also have animals that forage on both age classes, during the nighttime, maybe shallow diving, during the daytime they go to the bottom. This will make the relationships unrelated as well.

In addition to our spatial patterns we want to look at how the dive behavior changes. On the top here this is the echosounder data, this the surface to the seafloor, I highlighted our small Pollock and the adult Pollock. You can see on the bottom is an example of a dive record, these records occur when a Saildrone cross paths with a fur seal within 4 km. So it is the exact same time and day although the fur seals record is a little longer to make it easier to see. What we see is the fur seals were diving to about 20 m, which is in the small fish layer, then she switches to the deeper dives, which appear to occur in that area.

The shift happens at about sunset, and could potentially be related to the migration of our adult pollock, they move up off the seafloor at night.

This is a great occurrence that happened, because we can look at the individual and their changing behavior but we want to look at patterns for the whole population.

As we saw the backscatter increase we saw a decrease in dive depth, an increase in dives to the mixed layer, and an increase of wiggles. Wigglers are up-and-down movements in the bottom of the dive which are thought to be related to prey capture. This behavior reflects what we expect from the age-0 pollock, they will be in the shallow water and stay at or above the mixed layer and here's an example of what this looks like, the behavior, overlaid on some representative data.

As we saw the backscatter from the adult Pollock increase and we saw the dive depths increase, number of dives decrease and the number of wiggles decreased. This is more reflective of the benthic or bottom foraging strategy which would relate to these animals targeting those big fish that are found on the seafloor. You can see the dives are longer and there are fewer dives per hour..

We have video that can confirm our interpretation of these behaviors in relation to the fish.

This is video, when she turns you can see her ears and eyes, she is moving through a large school of small fish. You can see those wiggles that I talked about, up-and-down movements. The data is empathic it confirms what we suspect, which is something you cannot do without video or visual evidence. That was the shallow driving -- the shallow diving strategy.

This swam straight to the bottom, she will catch a large Pollock. She has to take this fish back up to the surface. We know without actually looking at the dive depth, we know she is on the bottom. In addition to the primary goal of mapping prey and related behavior, we are interested to assess if the Saildrone can conduct focal follow studies. These studies occur when researchers go out and identify an animal and observe its behavior over a period of time.

As you can imagine, these studies are limited in their time and the space that they cover and they require a large amount of effort. What if the Saildrone follows the animals and collects the same data?

The goal was to target an animal for two days and measure key metrics around the forging path. These tracks here, these are hourly locations of a trip for the tracked animal, there is purple for 2016 and green for 2017 and the orange highlights are where the saildrones follow those individuals.

The locations are intermittent and the Saildrone goes to the next location and they follow the

animal. If you can zoom in, you can see this in closer detail, we tested six focal follows and we look at accuracy based on time separation and distance separation. So we have our path of the Fur seals and the path of a Saildrone, the average distance separation was less than a kilometer for the duration. Which is pretty accurate given the fur seal locations come with errors. For the time separation we took a point along the fur seal track and calculated how long it took the Saildrone to get to that same point.

That was about 10 hours. In 2016 we started the process with the time separation, we started with a plan of sending the Saildrone 12 hours behind the Fur seals because we had no idea that the Saildrone will continue to get locations or if it would end up stuck waiting. The plan was the Fur seals would go to the locations and the Saildrone would follow, every location you get the location. The best follow in 2017 was on average, six hours behind and just over 1/2 km between the two. During this study, the Saildrone was less than one hour away from the Fur seals this was proof that the Saildrone makes a good tool to do the studies, we identified a number of ways we can improve especially with the time separation and we think future studies in this type of work can be valuable.

To summarize about the Fur seals and the Saildrone mission, the saildrones were a great platform to map our prey distributions , by simultaneously tracking behavior, and mapping needs resources we can see how the behavior changes, the ultimate goal is to link the information to measures of reproductive success.

The goal is that this information can be modeled to help predict how Fur seals will respond to changes in the future .

These results and understanding linkages, could be valuable for conservation. It is valuable for fisheries as well.

The next steps, we want to finish the data analysis. We have two years of data that needs to be completed, one of the goals is to continue our multi-division collaborations, we see how this exponentially increases our science and we hope the other researchers agree that so much more can be done when working together.

We want to start to use this information to integrate with our historic data collection, we have over 800 animals that were tracked in millions of locations, by having an understanding of these behaviors, we can interpret those historic data into the context of these relationships.

We can start to use the Pollock data as well, there's a lot of information from surveys, they can help us interpret what we saw in the past and predict what we expect to see in the future.

We want to see our Fur seals integrated into the Bering Sea model, the research modeling group has a number of models that they are working with, as a predator, we think the Fur seals would be a valuable addition to these models, we can provide information spatially and by age class which can help with stock assessments.

There is 2018 data occurring now, there are two missions schedule. The first mission is looking at ocean acidification, assessing physical circulation, and the second one is an acoustic survey, looking at the state of Arctic cod so if you want more information, I refer you to the information listed on the slide.

I want to acknowledge all the team members. Everybody worked together to achieve goals and we have worked together as a team and we have completed ecosystem research on a large scale in the Bering Sea. Here are some funding sources.

Any questions?

[Applause]

Thank you. Any questions in the room?

Could you do anything connecting forging with reproductive success?

That is where we want to go, we have a demographic project that has been going on that looks at the rates and variables. Unfortunately these are done at different sites because of logistics. We have information so we can start to link items and relate them to the animals. That is where we want to go, but we're not there yet.

How do we plan to do the data lag with this large amount of data? How does it go into models in the future if we have all the processing in between?

That is a question we are struggling with, especially the echo sounder, it's a long time to figure out the best plan of processing and that meant all our fur seals data had to wait until we had the echosounder data. That will be a challenge and we have limited staffing we feel that keeps adding on more and more so in the future that is something we need to address and how to move through this faster.

How did you get so many more KM in 2017? There are fewer days. Is there a relationship with speed and resolution of data?

That is a great question. They modified the Saildrone, we are now on generation 4, it increased our speed in 2017, it was larger in 2017, you can see the Saildrone, so that changed the performance of the Saildrone, we covered a greater speed and distance.

How big is it?

4 1/2 m above the surface. It is about 8 feet below the water and about 20 feet long.

It looked much smaller in your video.

It was to give you an idea of scale.

There were volcanic eruptions. Any seals on the islands? Do you know if they relocated?

We do not do a lot of research out there, it is logistically challenging to get to. We have past studies but none in the recent years. The last one was in 2015. They took a boat, they wanted to get a glimpse of what was going on. There were animals on the island. I don't know if those in almost -- I don't know if those animals got off the island during the volcano activity. The Pups would not be available to escape. They cannot swim that young..

Did you measure environmental variables on the Saildrone in addition to acoustics?

We measured environmental variables, they were running continuously. The variables we mentioned are listed here, we had wind speed, surface temperature, chlorophyll, water temperature, all these things are measured along the entire mission for 2016 and 2017 as well.

The results for the whales, there were challenges on the surface vehicle. They best deployed below the surface to avoid sounds from waves. The surface splashing was in the band width of the right whale calls so it was difficult to identify anything in the region. There is a marine mammal commission report that tells some of the results, a few call in some areas may have been identified based on the Saildrone data compared to mooring data. In 2017 there were redesigns, the outriggers were removed, they lessened the noise. But in 2017, we had a very windy year. So the wind noise was in that region of the right whale calls. It was irregular which made it hard to hear in that bandwidth..

Is not the ideal platform in its current state for passive acoustics for right whales. But other animals were recorded. If you're looking for beaked whales it would be a great platform.

Any thought given to using a different platform? I believe they are working with other platforms, they are looking into equipping gliders. Now they have this autonomous acoustic recorder, moving it to a different platform will be a good situation.

There's only a couple of moving parts in the Saildrone and it makes it durable in severe conditions. And then you add on other things, that could be a future change.

Any analysis of the extra data you collect it?

That is one of our goals, it is not a top priority, but all the data is available, we have all the data in other years, if you start to find relationships between fur seals and environmental conditions that we can interpret past years with the environmental data. It is something we have the ability to do but we did not do it yet.

You mentioned the data was compromised on windy days. How was it compromised?

That's a question more suited for the acoustic team. You get gaps in the echo sounder information, it is hard to interpret what is going on, there are problems with high winds and you can get bubbles in the water and they impact the echo sounder as well. I don't think it is easy to adjust, but we learned that the Saildrone has a storm mode where they can actually move in the direction that can still collect data, instead of running against the storm where there was extra noise, but if they ran in the storm mode, it was a little quieter. That can be made if you know you are in bad conditions.

CDOM is a variable how does this factor?

That is a question for the oceanography team. Contact the people at the bottom of the screen. They can provide more information. We did not use that for any of our work for the fur seals but that is information they can provide.

Thank you.

Can you show your graphic, the population abundance again?

I believe this was in the 70s. Since it has been listed, we have gone through significant population decline. We keep bringing that to the forefront, it is threatened, depleted and declining.

[Applause]

[End of transcript]